Gulf of Alaska Pollock Model Updates

Cole Monnahan

Alaska Fisheries Science Center

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Executive Summary

This stock has undergone several major changes in the last few years, in particular the transition to TMB in 2023 and a CIE review in 2024. In 2025, only several minor changes are proposed for this assessment. First, a model was explored that excluded the age-3 fish from the Shelikof Strait survey, per an SSC recommendation, although this is not recommended nor proposed as an alternative model at this time. Second, the Shelikof Strait and summer acoustic survey data were updated based on improved technology and workflows, as recommended by the AFSC's acoustic program. Third, the way the initial numbers at age are estimated were updated to be more in line with other AFSC assessments and be more statistically defensible. Finally, more priors were added to the model to stabilize estimation. I call a model that includes all changes (but leaves the age-3 Shelikof fish in) as proposed model 23e. The impacts on biological reference points and management recommendations are minimal compared to results from the accepted model (23d) in 2024. **I recommend adopting model 23e in 2025 for the 2026 fishery.**

Table 1. Management implications for proposed models using data from 2024.

Model	SSB (2024)	B0	B40	B35	FOFL	FABC	OFL (2025)	ABC (2025)
23d: 2024 final	243,078	535,000	214,000	187,000	0.321	0.271	210,111	181,022
23e	252,704	539,000	216,000	189,000	0.319	0.269	216,027	186,208

Proposed models

The GOA pollock ADMB model was converted to Template Model Builder (TMB; Kristensen et al. 2016) in 2023 and named model 23 (Monnahan et al. 2023). TMB extends ADMB's functionality to allow for a state-space formulation, specifically the estimation of process errors by minimizing the Laplace approximation to the marginal negative log-likelihood. It can be configured to closely match the ADMB approach of penalized maximum likelihood.

The GOA pollock TMB assessment model, an accompanying R package, files to reproduce past accepted models, and the SAFE markdown files are developed on a public repository at https://github.com/afsc-assessments/GOApollock.

Removing age 3 fish from the Shelikof survey

The age 1 and 2 fish in the Shelikof Strait survey were removed from the model in 2024 based on feedback from the CIE review and an acknowledgement that they were fitting poorly and misconstruing estimates of recruitment. The logic behind this was that immature fish do not reliably migrate to the Strait to spawn. Since age 3 fish are not fully mature, the SSC recommended an alterative model run without age 3 fish. To implement this recommendation, I removed the observed proportions at age 3, adjusted the input sample size by dropping age 3 observed fish, and renormalized the observed proportions (m24_2_drop3s). Selectivity at this age was also forced to be zero. The SSB estimates were very similar (Fig. 1) and the fits to the age 4+ composition data was not meaningfully improved (Fig. 2). I therefore do not believe this model represents an improvement, and note that understanding how to best model this survey, including reincorporating the age 1 and 2 indices, is an active research track with ongoing collaborations with the AFSC's acoustics group (MACE). **This model alternative is thus not considered subsequently.**

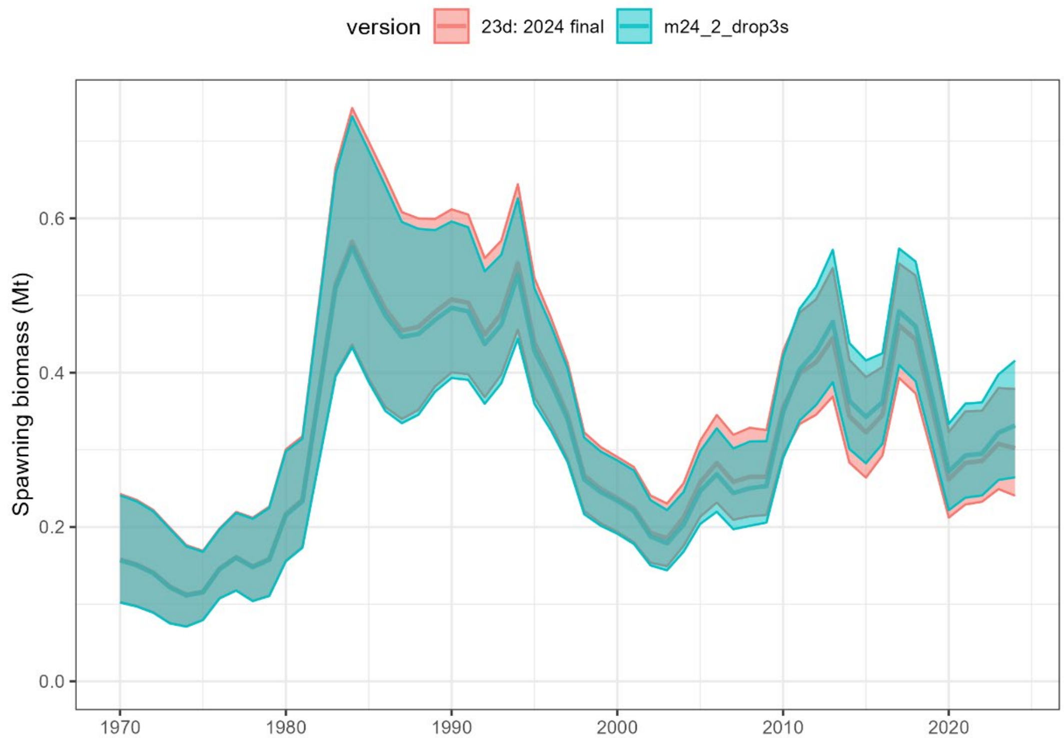


Figure 1. Comparison of SSB when dropping the age 3 Shelikof fish.

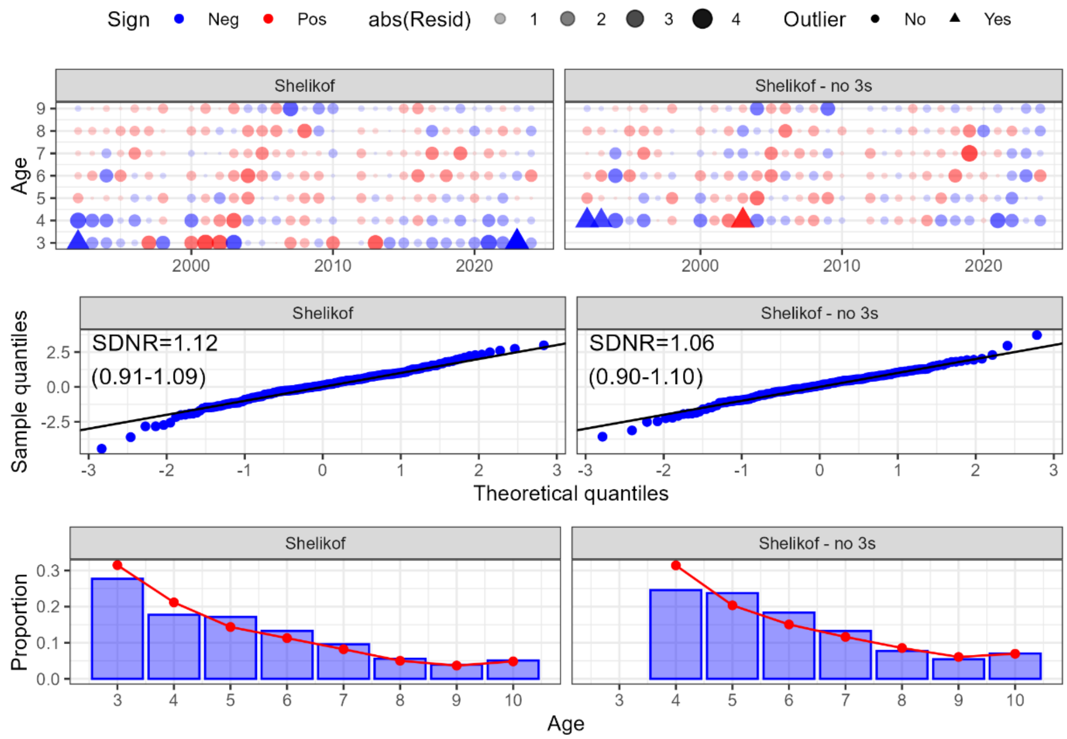


Figure 2. Fits to the Shelikof age compositions with (left) and without (right) the age 3 fish.

Updating the initial age structure formulation

Model 23d (and historical models) initialized the age structure by assuming no fishing and thus equilibrium, and using the initial recruitment deviation (age 1 fish in year 1970) to fill out the age 2-10+ fish in 1970. The initial ages were therefore dependent on a recruitment deviation that was also used for the initial cohort size and thus used twice. Furthermore, the same penalty may not apply to this deviation as the recruitment deviations, particularly if fishing effort was not zero. The approach taken here is unique at the AFSC (as far at the author knows) and statistically is hard to justify because this first recruitment deviation represents something different than the rest, and breaks the "exchangeable" statistical assumption underlying random effects.

To rectify this, I restructured the initial ages as follows. First, I estimate a new parameter *log_initN0* which represents the deviation from mean recruitment (in log space) of age 1 fish in 1969. This is estimated with the prior $N(0,1.0^2)$ where the variance of 1.0 is different than σ_R. $N(1970,2) = \exp\left(\mu + log\_initN0 - M(1)\right)$ where μ is mean log recruitment and M(1) is natural mortality at age 1. Subsequent numbers at age are calculated as $N(1970, a+1) = N(1970, a)e^{-M(a)}$ through age $a = 9$ and the plus group is $N(1970,10) = \frac{N(1970,9)e^{-M(9)}}{1-e^{-M(10)}}$. This approach has the advantage that the first recruitment deviation only is used once and thus is exchangeable. This formulation (m24_1_initN) led to an estimate of the new deviation for age 1 fish of -0.657 with a standard error of 0.323, and had a smaller initial SSB, but a negligible impact on model estimates of SSB after 1978 (Fig. 3), because reliable age data do not occur until after this initial age component is gone from the population. **Given its superior statistical formulation I recommend adopting this new approach and incorporate it in all subsequent models.**

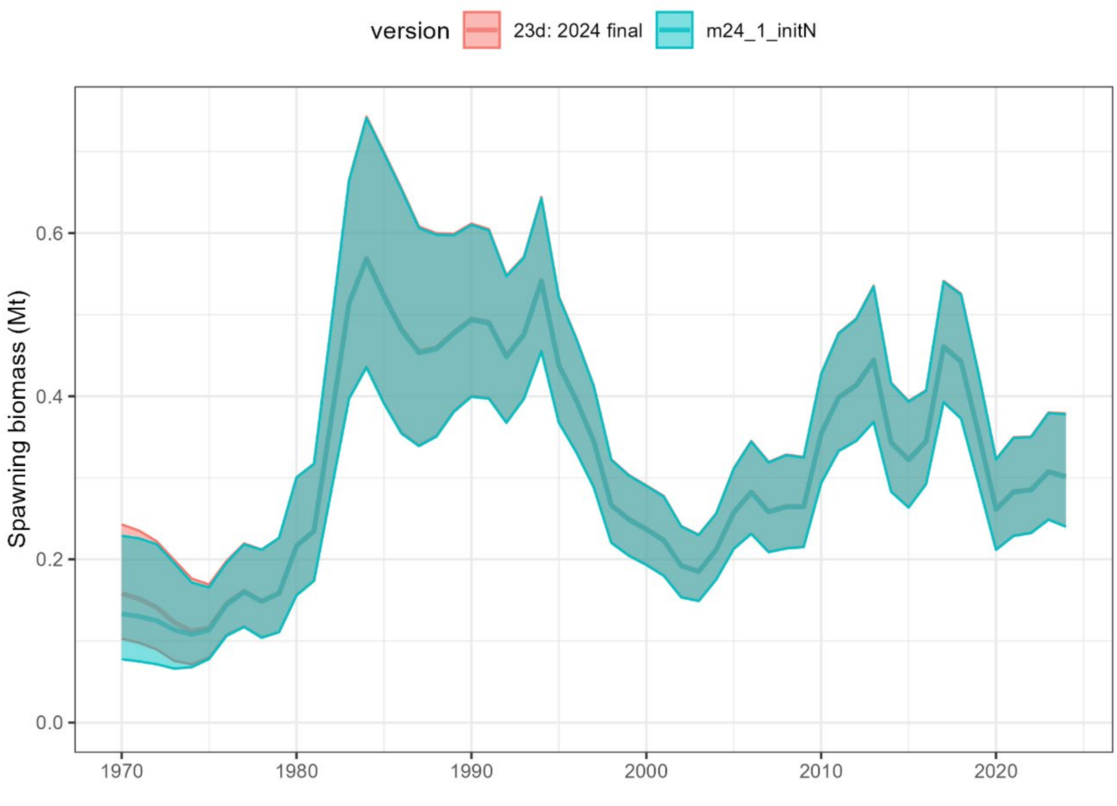


Figure 3. Comparison of SSB when updating the initial age structure formulation. .

Adding additional priors on AR(1) process parameters and selectivity

The 2024 model (23d) included stronger priors on parametric selectivity parameters and the interested reader is referred to the 2024 September Plan Team document (link) which discusses the philosophy and approach used, with scientific references. Here, I added new priors on the parameters controlling the AR(1) smoother on the maturity covariate (mod24_3_add_priors). An AR(1) autoregressive process is one in which the current value is based on the immediately preceding value and an estimated correlation parameter. Specifically I put a N(0,1.5) on the logit of the AR(1) correlation, which roughly equates to a uniform prior from (-1,1) on the correlation. A stronger prior was also put on the parametric selectivity for the Shelikof Strait survey descending logistic curve. These additions have a negligible impact on the model estimates, but do stabilize it when doing jitter analyses and MCMC, and so are seen as beneficial. **I recommend adopting these priors and use them in the subsequent models.**

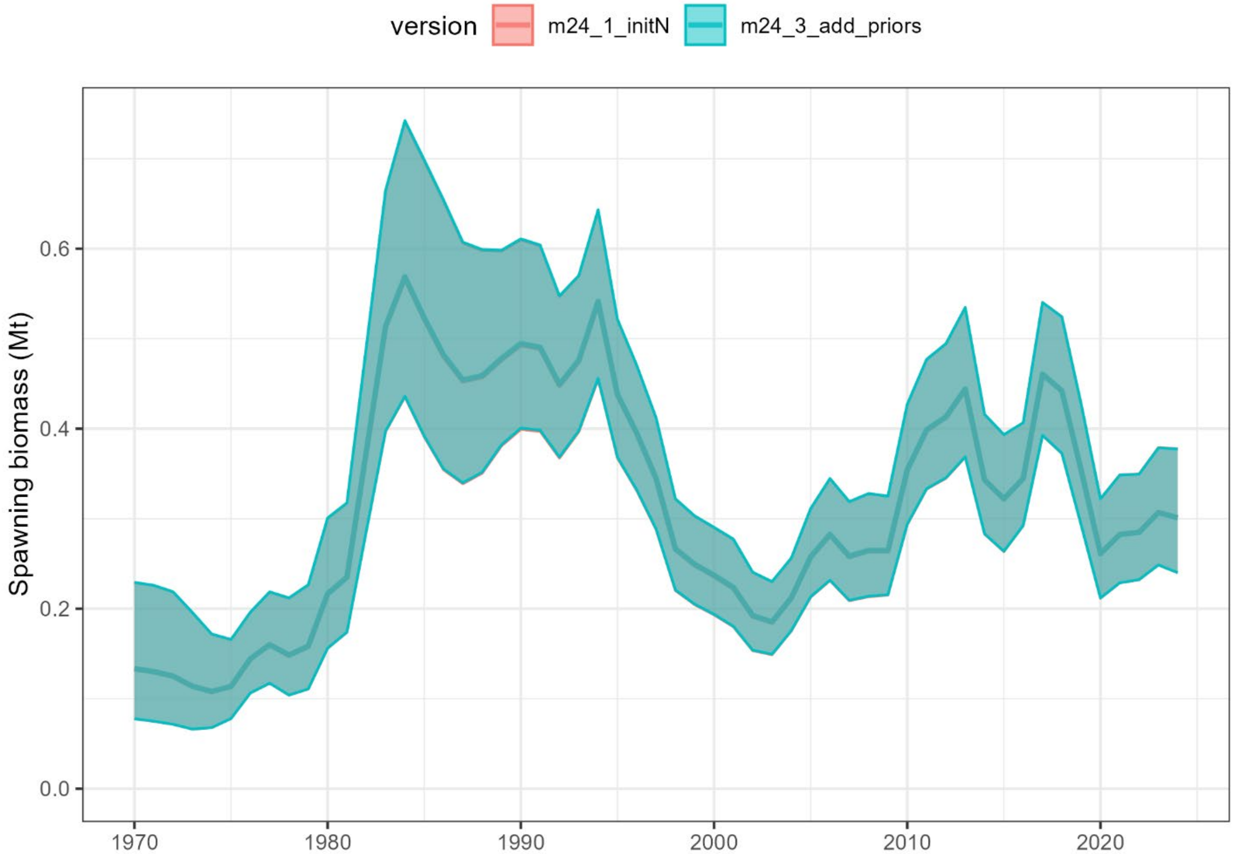


Figure 4. Comparison of SSB when adding the priors to the previous model. Model m24_3_add_priors builds off the m24_1_initN model.

Updating the Shelikof data streams

This year the MACE program supplied updated data series for winter Shelikof Strait acoustic-trawl (AT) surveys from 2008-2024 and summer Gulf of Alaska (GOA) pollock AT surveys from 2013-2023. This includes biomass indices, age compositions, and maturity-at-age data which affect management quantities, but also biomass by region, length compositions, and other quantities which are used for spatial apportionment and shown in the SAFE to give context to these surveys and results. The changes arise from a reanalysis of historical AT survey data following the analytic approach currently used by the MACE program as described in McGowan et al. (in prep). The historical assessments were done by appending a new year of data onto the existing data input files, which implicitly assumed that no updates had been made to data from previous years. The updated data this year incorporate changes and upgrades in equipment and analysis approaches that have occurred since 2008 to better account for sampling biases and improve the accuracy and precision of survey estimates. These include associating backscatter to the nearest haul; proportionally apportioning acoustic backscatter to all organisms in selectivity-corrected trawl catch using updated net escapement functions (e.g., Williams et al. 2011, Honkalehto et al. 2024); using species-specific target strength-to-length relationships for forage species; rescrutinizing acoustic data from summer GOA surveys to include mixed-species aggregations previously excluded from historical analyses; and weighting maturity estimates by local abundance in the winter Shelikof survey. As these steps have been incrementally incorporated in the current year's analysis of AT survey data, the reanalyzed data now reflect a standardized time series since 2008 in winter and 2013 in summer, while also including any other corrections to historical data that occurred after the data were originally submitted to the assessment author.

In general, the quantities for pollock changed by less than 5% (but with some exceptions). When used in the model (m24_4_update_acoustic), the results are fairly consistent, but with a slight increase in SSB in recent years (Fig. 5) with similar uncertainty. **Since these new data are considered the best available science, I strongly encourage adoption of them.** Moving forward, I will work with MACE to improve the data pipeline so that updating historical data is easier and done more often, when needed.

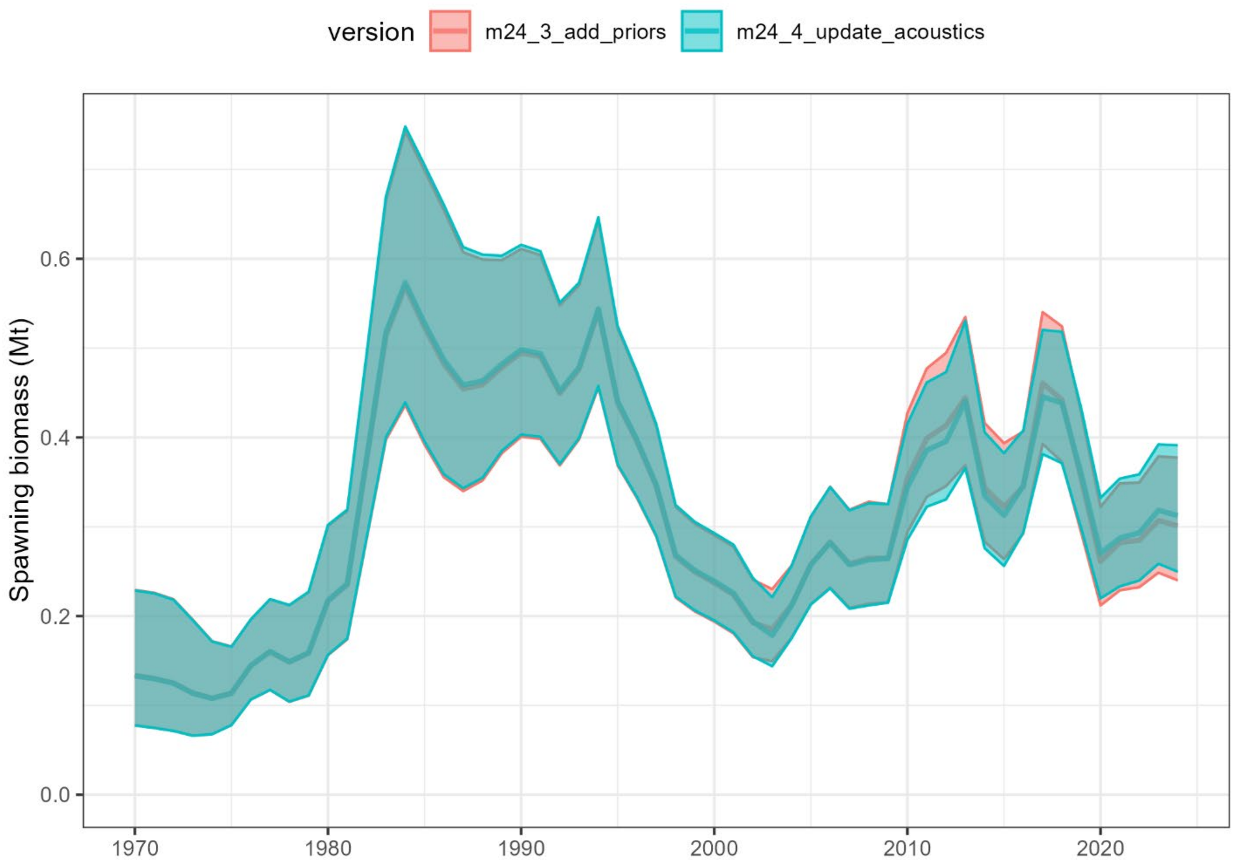


Figure 5.Comparison of spawning biomass when updating the Shelikof Strait data from 2008-2024 and the summer acoustic data from 2013-2023.

I propose model 23e to include the changes to initial age structure, additional priors, and the updated acoustic data products.

Model results

Results are only presented for the formally proposed model 23e and compared to 2024 base model 23d as needed.

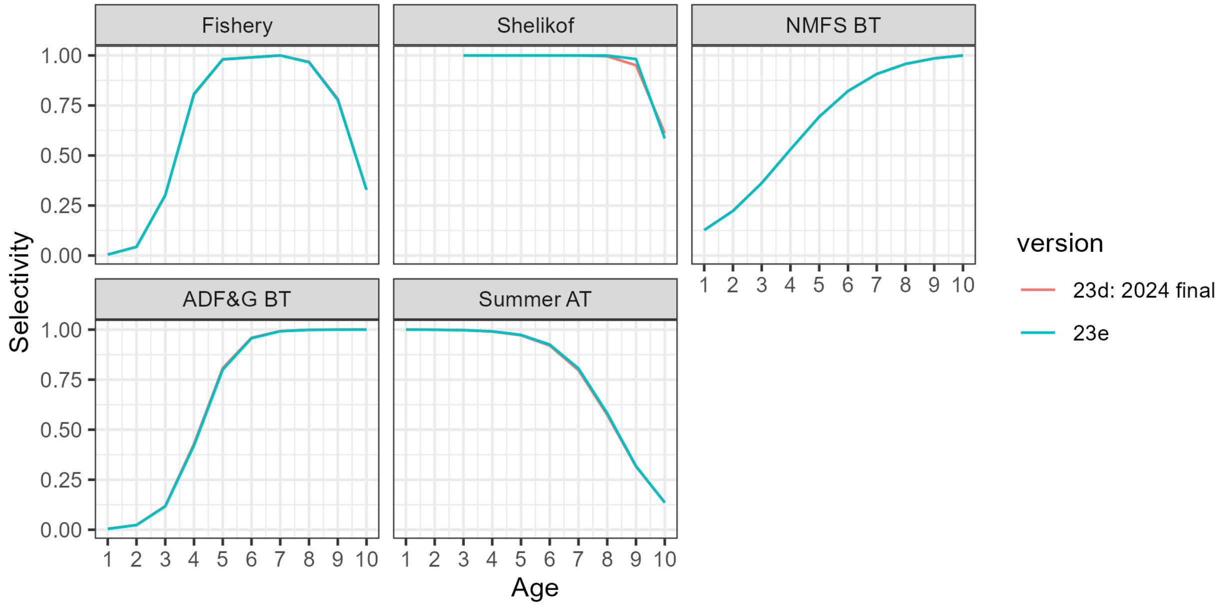


Figure 6. Selectivity estimates between candidate models.

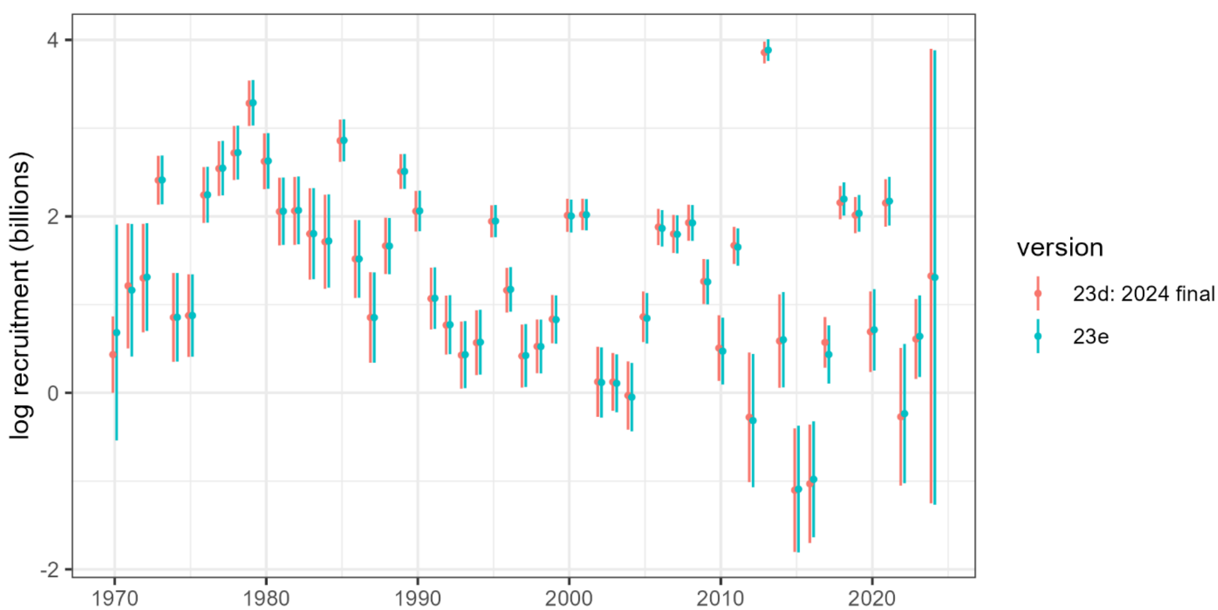


Figure 7. Comparison of log recruitment.

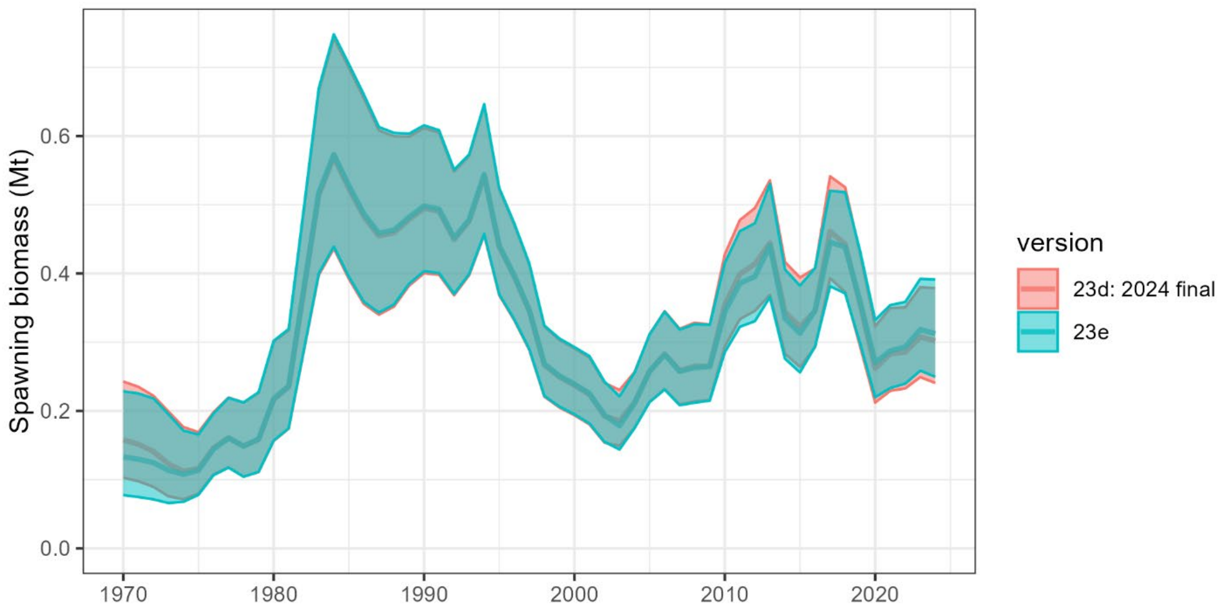


Figure 8. Comparison of spawning biomass.

Table 2. Parameter estimates for model 23e. Random effects (deviations) are excluded for clarity.

Parameter	Estimate	SE
log_initN0	-0.660	0.323
mean_log_recruit	1.307	0.183
log_slp2_fsh_mean	0.667	0.275
inf2_fsh_mean	9.629	0.129
log_slp2_srv1	1.296	0.695
inf2_srv1	10.094	0.147
log_slp1_srv2	-0.388	0.099
inf1_srv2	3.867	0.298
log_slp1_srv3	0.535	0.101
inf1_srv3	4.188	0.213
log_slp2_srv6	0.088	0.260
inf2_srv6	8.303	0.587
log_q1_mean	-0.692	0.079
log_q2_mean	-0.262	0.092
log_q6	-0.358	0.128
transf_rho	0.451	0.169
log_Ecov_sd	-0.023	0.130
Ecov_beta	0.326	0.033
log_DM_pars	0.013	0.169

log_DM_pars	-0.194	0.183
log_DM_pars	-0.070	0.223
log_DM_pars	0.489	0.338
log_DM_pars	0.988	1.079
log_q6	-0.358	0.128

Model evaluation

Convergence, estimability, and stability

All models converged by standard diagnostics. Specifically, Newton steps using the inverse Hessian were successful and reduced the maximum absolute gradients to less than 1E-8. The Hessian matrices were also all invertible. A jitter analysis was performed on the base model and the proposed model for 2025, 23d and 23e. For each jitter analysis new initial values are generated by multiplying the fixed effects initial values by random draws from a U(.9, 1.1) distribution, while leaving random effects initialized at zero. This was repeated 100 times. Both models found the same mode and thus are considered stable (Figs. 9, 10). This is largely an effect of adding priors on selectivity and other fixed effects. Overall the new proposed model converged well and is stable with respect to initial values.

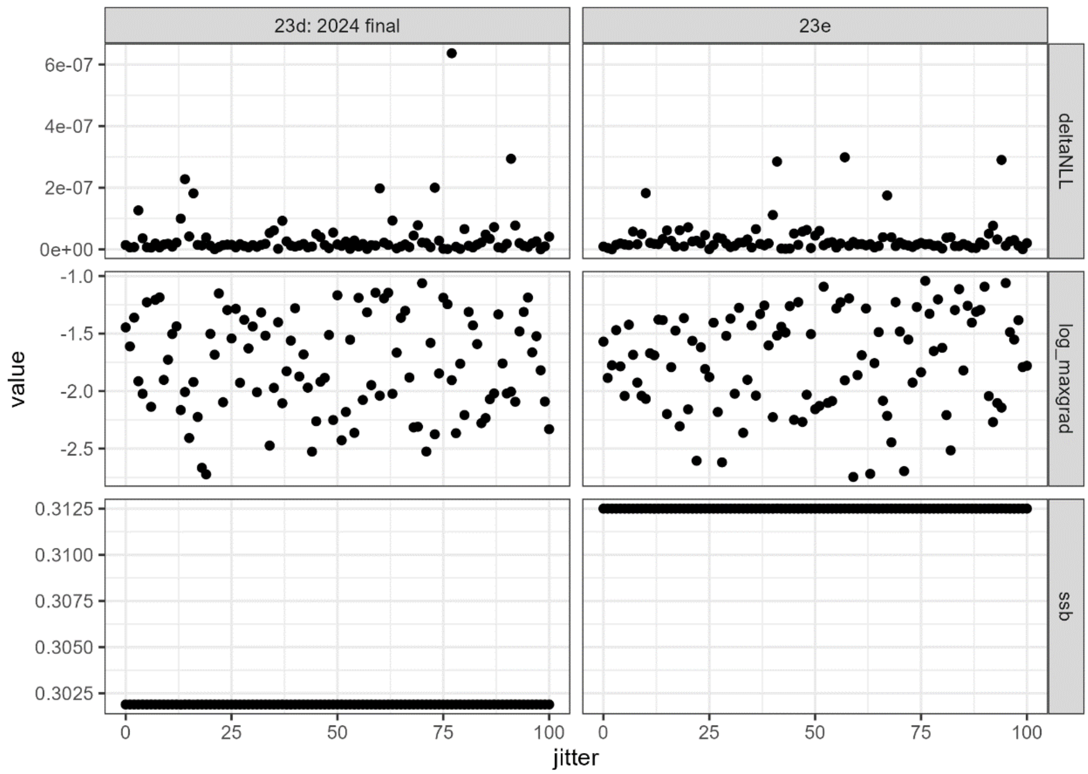


Figure 9. Jitter results for the change in NLL (deltaNLL), maximum gradient, and terminal spawning biomass (SSB).

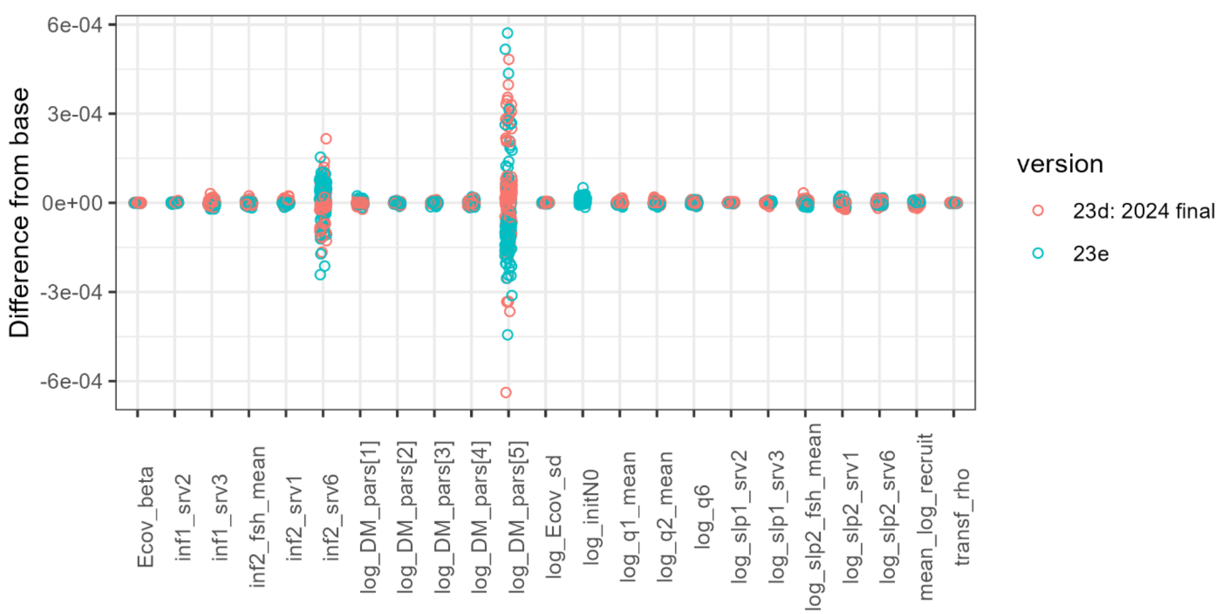


Figure 10. Jitter results for fixed effects, represented as absolute differences from the base model.

Posterior sampling was done via the adnuts R package (Monnahan and Kristensen 2018, Monnahan 2021), including a new algorithm in development which utilizes the joint precision matrix to decorrelate the model prior to sampling and which makes sampling much more efficient and works when process errors are estimated. Model 23e samples well with MCMC, and this indicates the posterior geometry is reasonable (Fig. 11). Efficient sampling is primarily due to the regularization priors on selectivity.

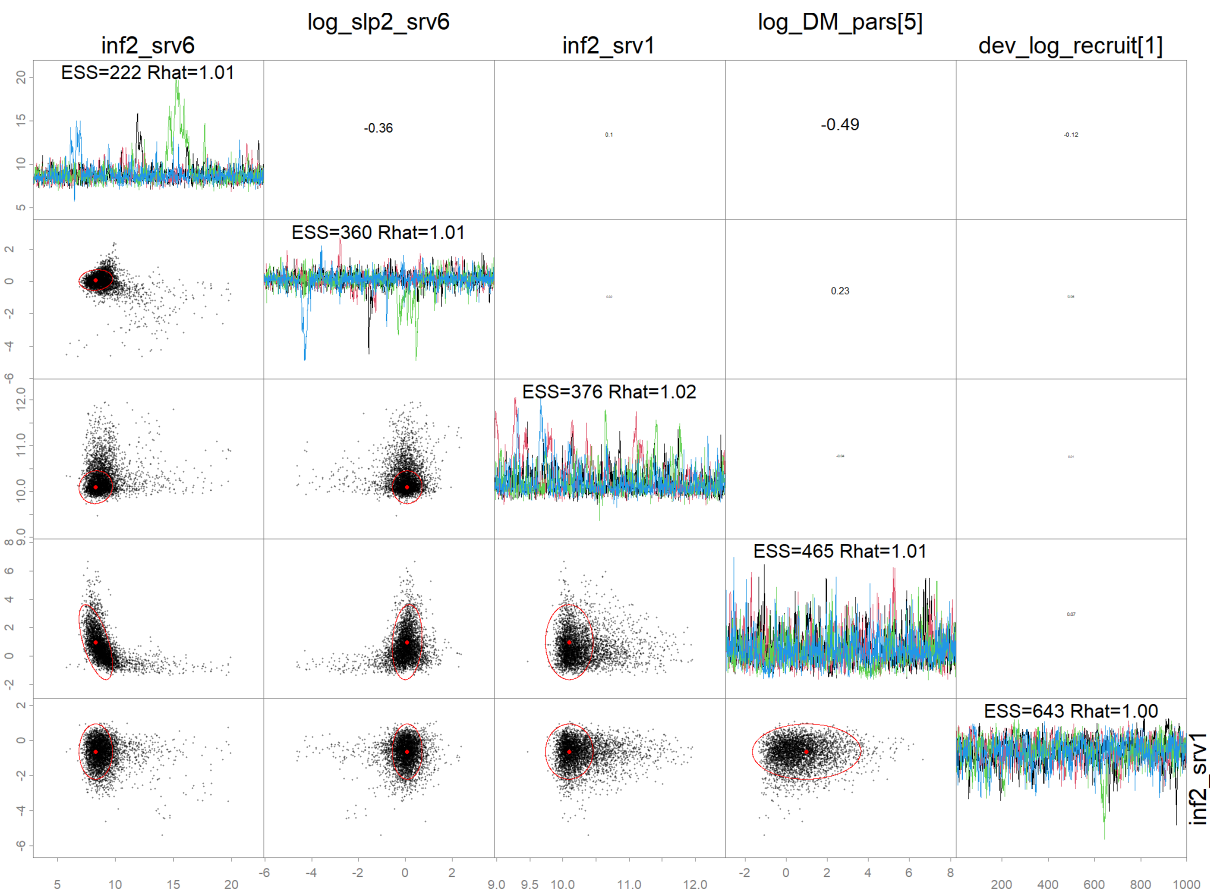


Figure 11. MCMC analysis where the diagonal panels show the trace plots, while lower triangle panels are pair-wise posterior samples (black points), the MMLE covariance (red point and ellipses) and green points show no-U-turn divergences. Note the effective sample size (ESS) and large Rhat values given on the diagonal panels. The parameters shown are the five with the lowest ESS (i.e., the slowest mixing).

Posterior samples are not directly used for management recommendations but are used in the calculation of probabilities of depletion. It is clear that the new model will be effective at this because sufficient.

Finally, a self-test simulation experiment was conducted for model 23e which involved simulating 100 data sets from the fitted model and refitting the matching model, comparing the estimated outputs (SSB and recruits) against the original which is taken as the truth. For this year I did not resample the process errors but that would be an improvement in future years.

For model 23e both recruitment and SSB showed no signs of bias (Fig. 12). As expected the variance in relative error for recent recruits and early SSB is higher due to limited information in the data.

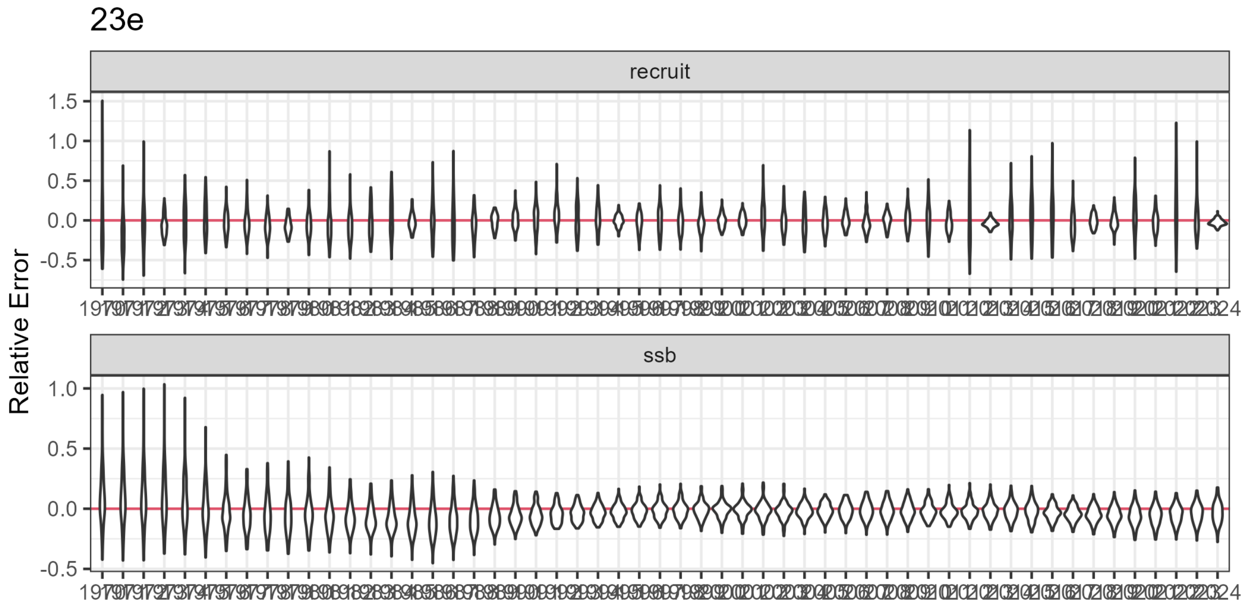
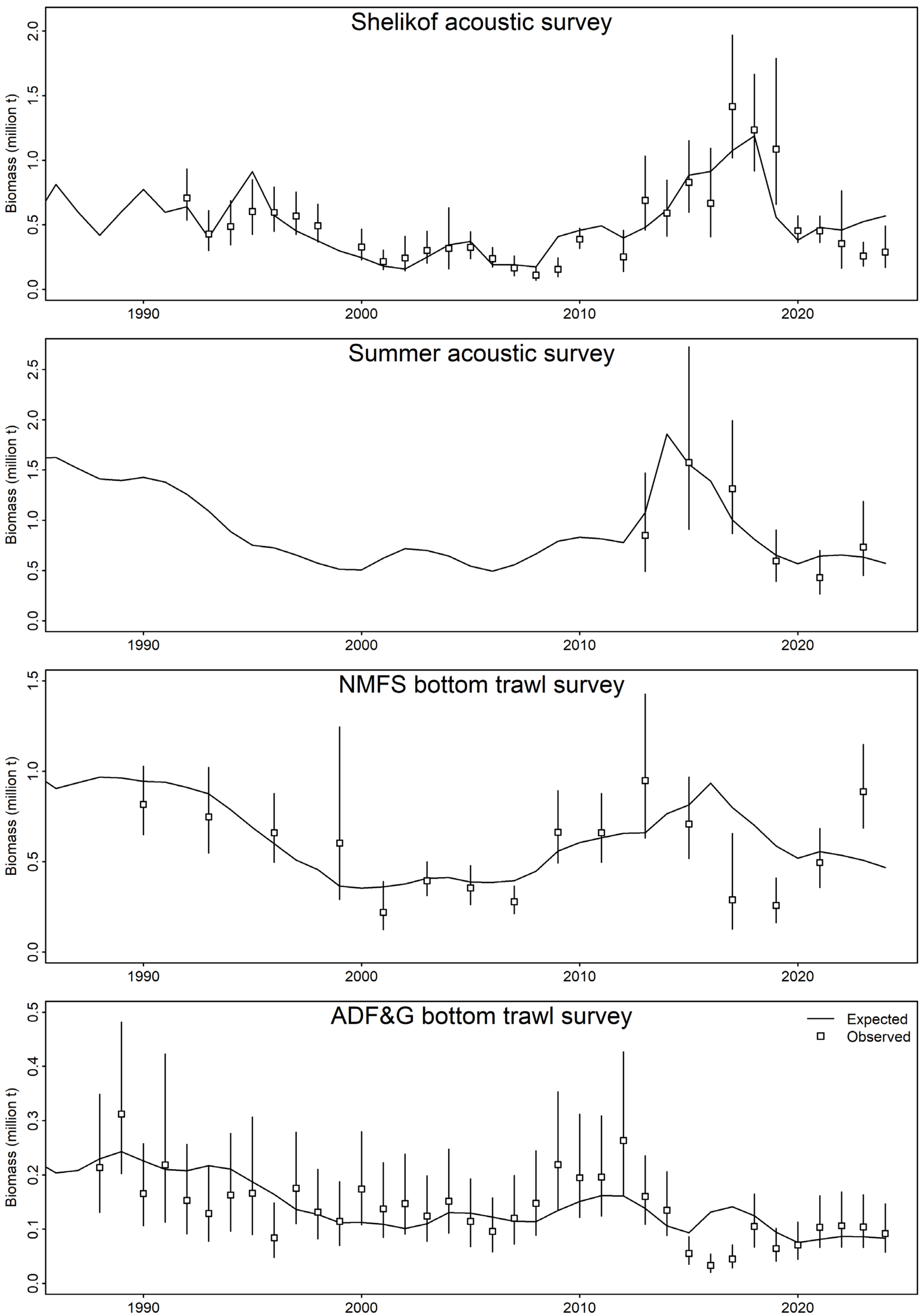


Figure 12. Results of self-test simulation for the proposed model 23e. Relative error is calculated with the original fitted model as the reference. The model exhibits no obvious signs of bias.

Model validation

Fits to the biomass indices are similar to model 23d (not shown), with the lingering misfit to the NMFS BT survey (Fig. 13).



Shelikof acoustic survey
Summer acoustic survey
NMFS bottom trawl survey
ADF&G bottom trawl survey
Biomass (million t)
Expected
Observed

Figure 13. Model fits (lines) to index data (points with 95% confidence intervals) for model 23e.

One-step-ahead (OSA) residuals were calculated externally via the afscOSA R package which uses the compResidual R package (Trijoulet et al. 2023). These age composition residuals are expected to be independent and standard normal under a correctly specified model, and deviations from this indicate lack of fit (Thygesen et al. 2017). Bubble plots, QQ plots, and aggregate fits (Fig. 14) indicate some lack of fit for model 23e, but fits are nearly identical to model 23d (not shown).

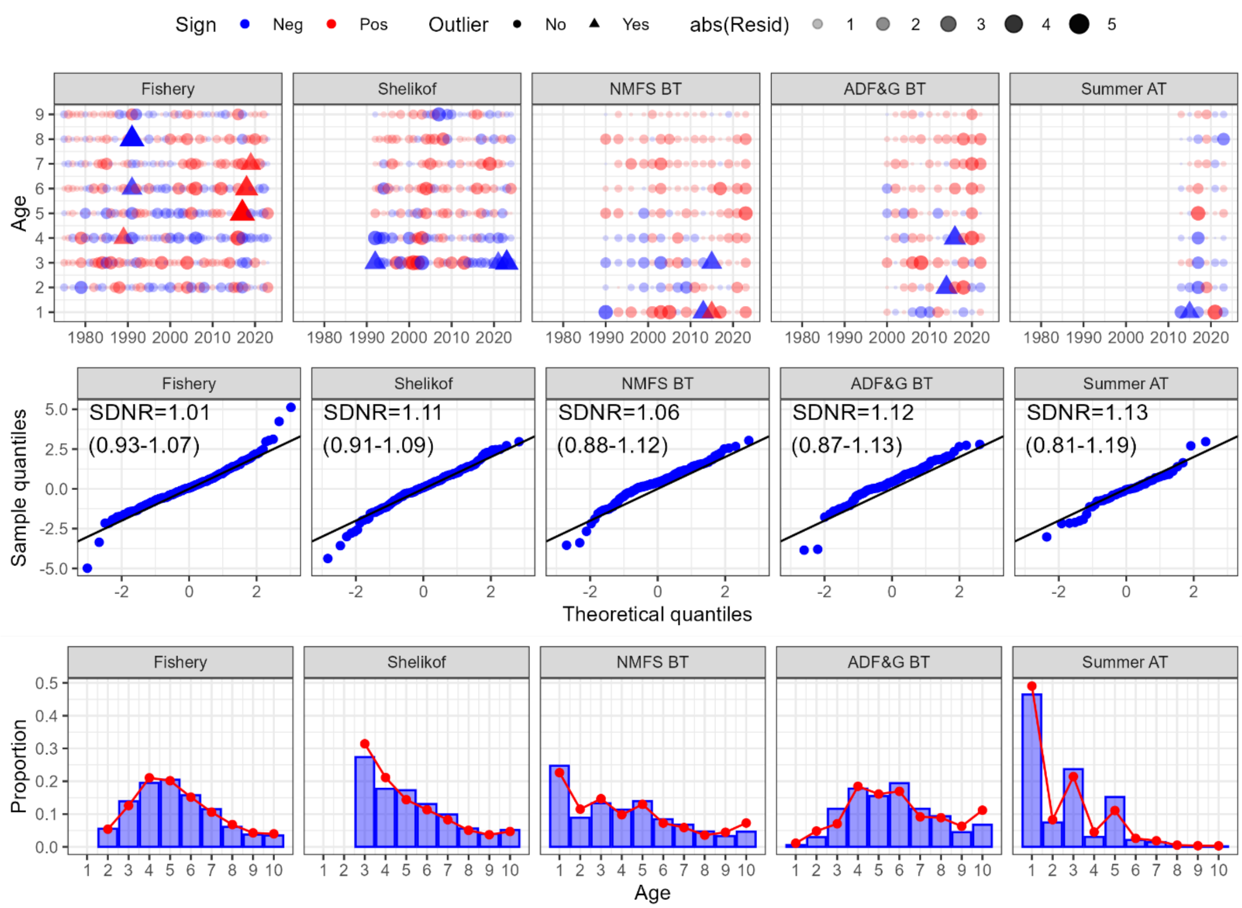


Figure 14. Fits to composition data from the afscOSA R packge. OSA residuals are calculated without the age 10 data and shown as bubble plots (top row) and quantile-quantile plots (middle row). The bottom row the aggregate fit across all years with data.

Retrospective patterns

The proposed model does not improve on the retrospective patterns from the base model (Fig. 15). Estimation of cohort size was also not affected in the proposed model (Fig. 16).

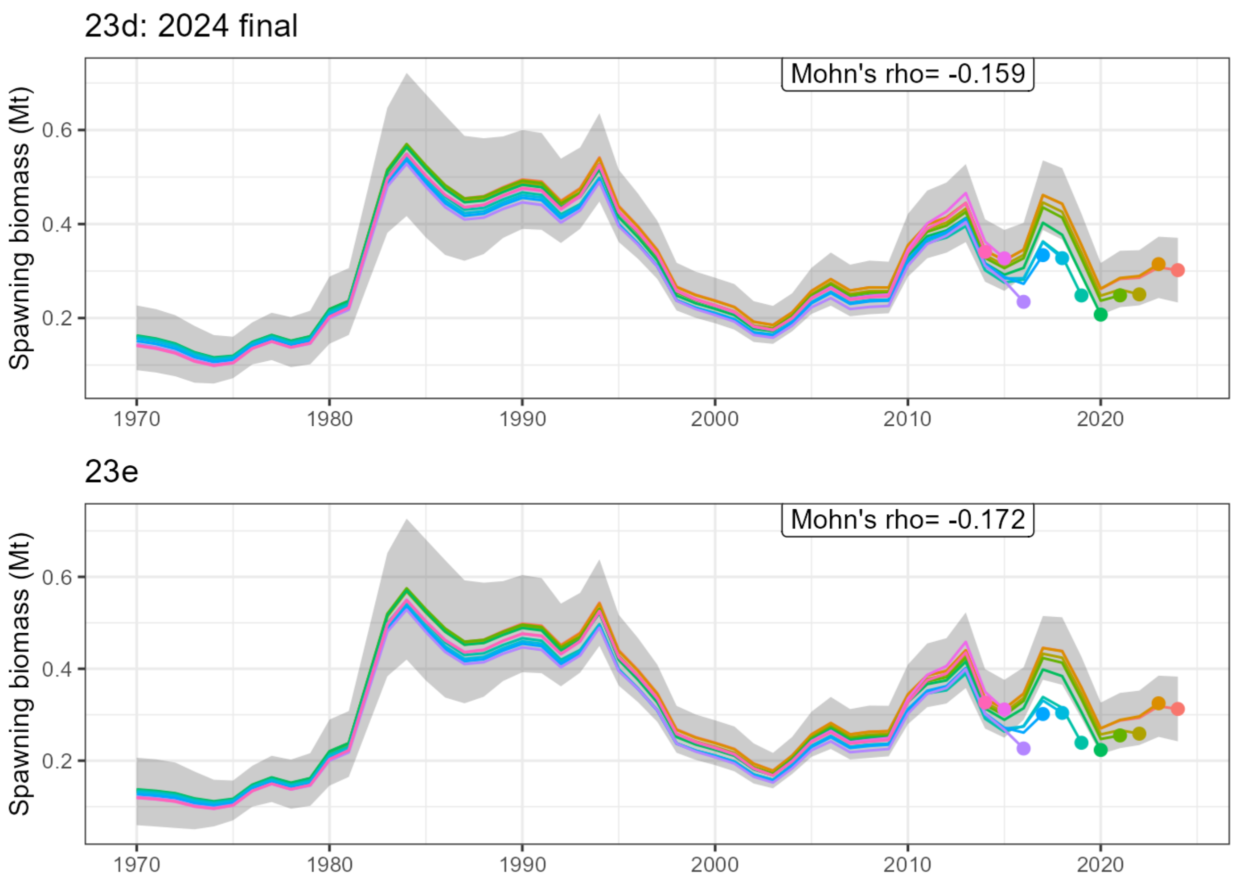


Figure 15. Retrospective fits for spawning biomass. The gray ribbons indicate the uncertainty from the base (peel 0).

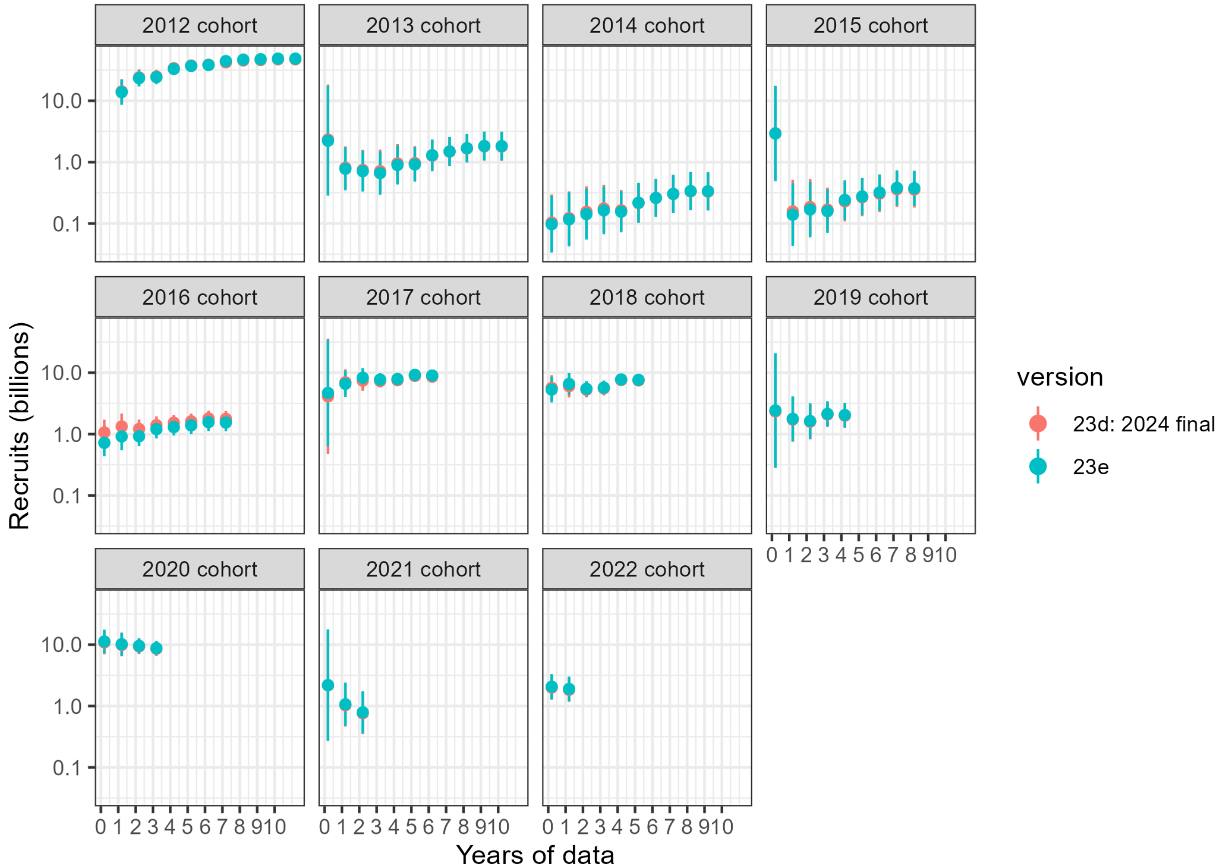


Figure 16. Recruitment estimates by cohort as data are added to the model, taken from retrospective peels.

Likelihood profiles

Likelihood profiles were run for two parameters that affect the scale of the stock: natural morality (*M*) and catchability for the NMFS BT survey (q2), where the latter has a strong prior known to mitigate uncertainty in scale for this stock. In both cases the only random effects marginalized were associated with the catchability link for Shelikof (the smoother on the observed covariate). Natural mortality is assumed aged-based and known in the assessment. This age-based curve was scaled up by multiplying by a constant, and *M*=0.3 at age 6 is used as a reference point for the *x*-axis in Fig. 17.

Initially a profile on mean recruitment, R0, was done, but was deemed ineffective and misleading because without a sum-to-zero constraint the deviations can offset the change in R0 and keep recruitment equivalent with only the recruitment penalty changing.

There was a strong total signal on *M*, but also conflict among the data sources (Figs. 17, 18). Similarly, the likelihood profile on q2, showed there was some clear conflict between Shelikof ages and the NMFS BT ages (Fig. 19).

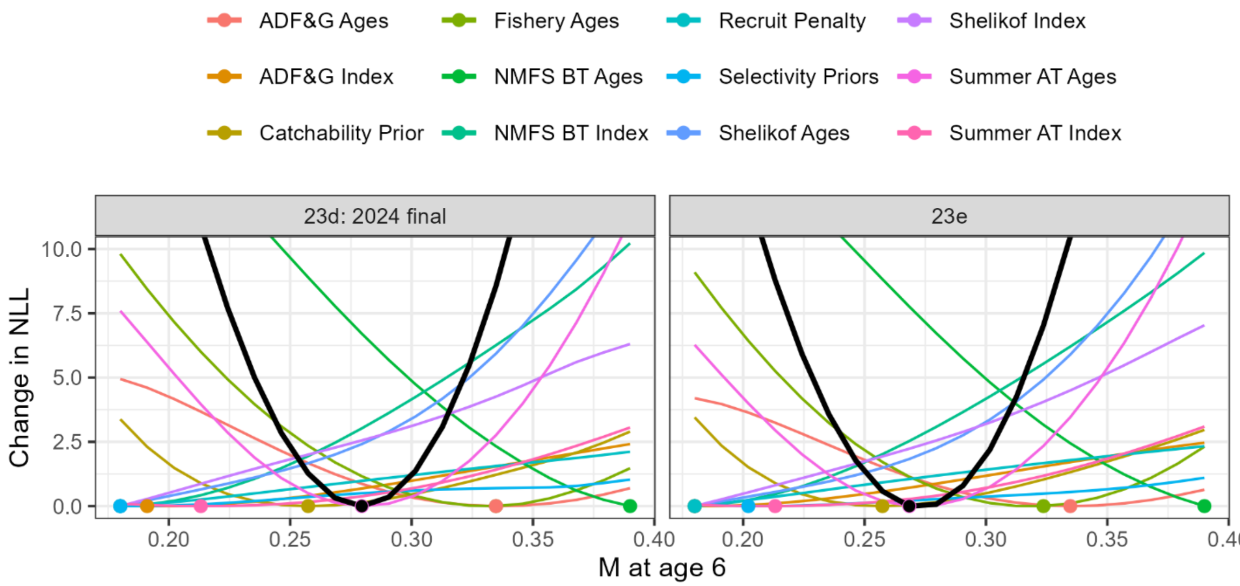


Figure 17. Likelihood profile across natural mortality (M), showing total (black line) and components (colors) which had non-negligible impacts with their minima shown as colored points. The model currently assumes age-based M, with age 6 assumed to be 0.3.

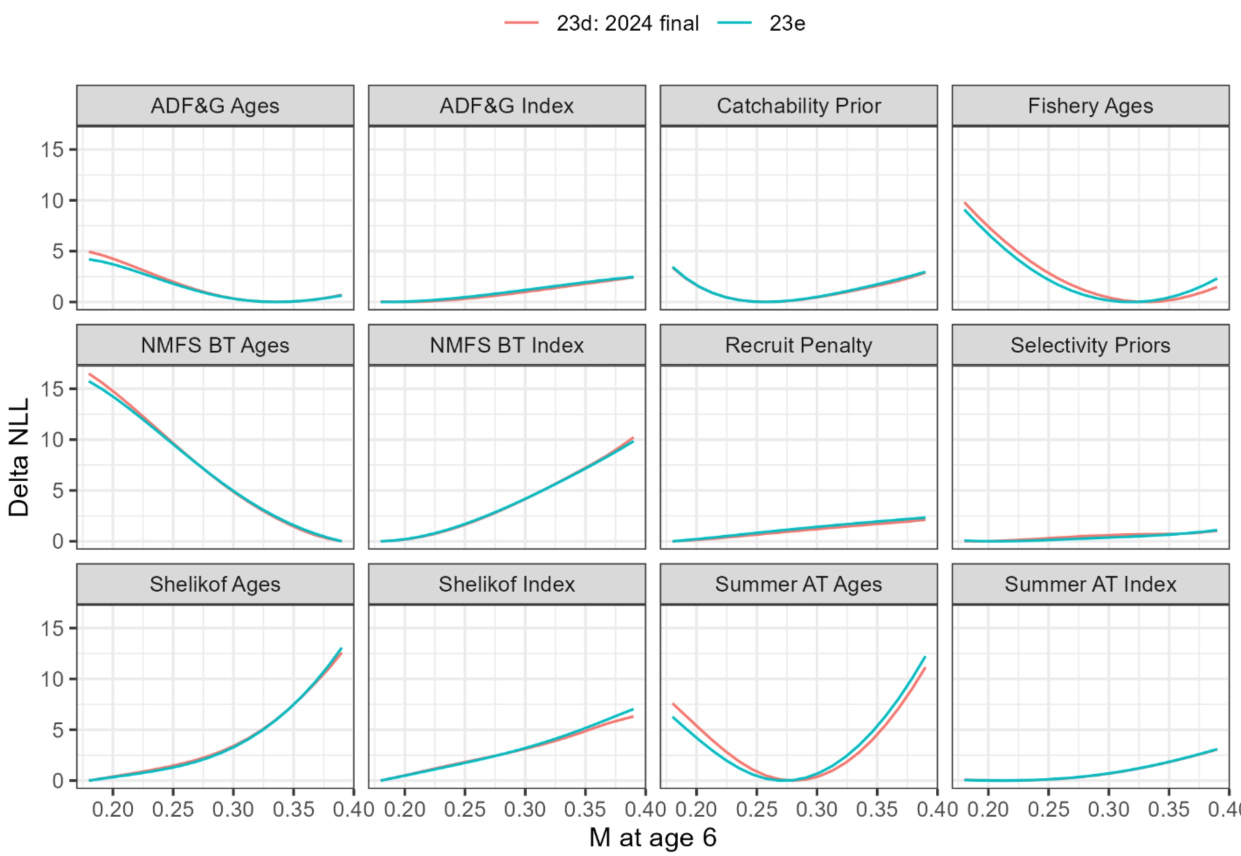


Figure 18. Profile likelihood results for natural mortality (M) at age 6, plotted by data component. A value of 0.3 is used in the model.

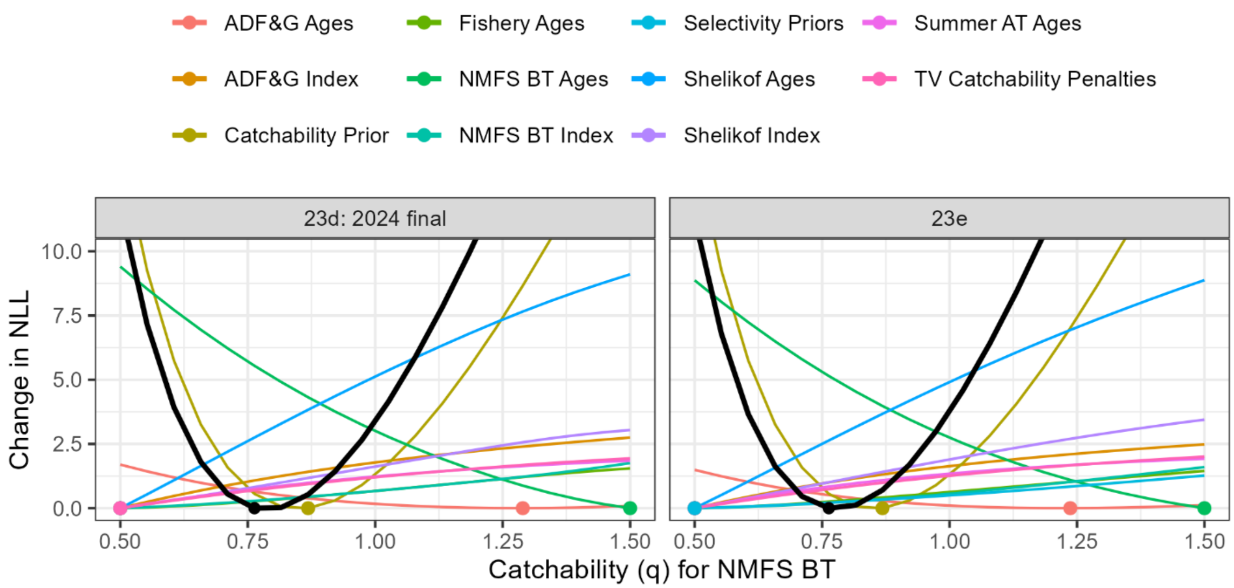


Figure 19. Likelihood profile across catchability for the NMFS bottom trawl (q2) showing total (black line) and components (colors) which had non-negligible impacts, with their minimal shown as colored points.

Sensitivity tests

Given the conflict in data sources identified above it is important to test the sensitivity of the model to the different surveys. I therefore reran the model leaving each survey out (indices, ages, and lengths, as appropriate). The model is insensitive to trends in SSB, and fairly insensitive to scale when dropping surveys. The key exception is the NMFS BT where the uncertainty of SSB increases, but also the absolute scale increases notably without the survey in it (Fig. 20). This is the survey with a fairly informative prior on q, and one that has recently fit poorly to the index (Fig. 13), as well as exhibiting conflict between its index and age composition (Figs. 17, 18). This sensitivity test was also presented at the 2021 September Plan Team (see page 13 of this report), and is a known issue with this stock. The difference this year is that the mean SSB has shifted up, whereas in 2021 the scale did not change as much and only uncertainty increased. As such, this presents a new issue with the stock that is likely related to the recent misfit to the index, but is independent of the model version used.

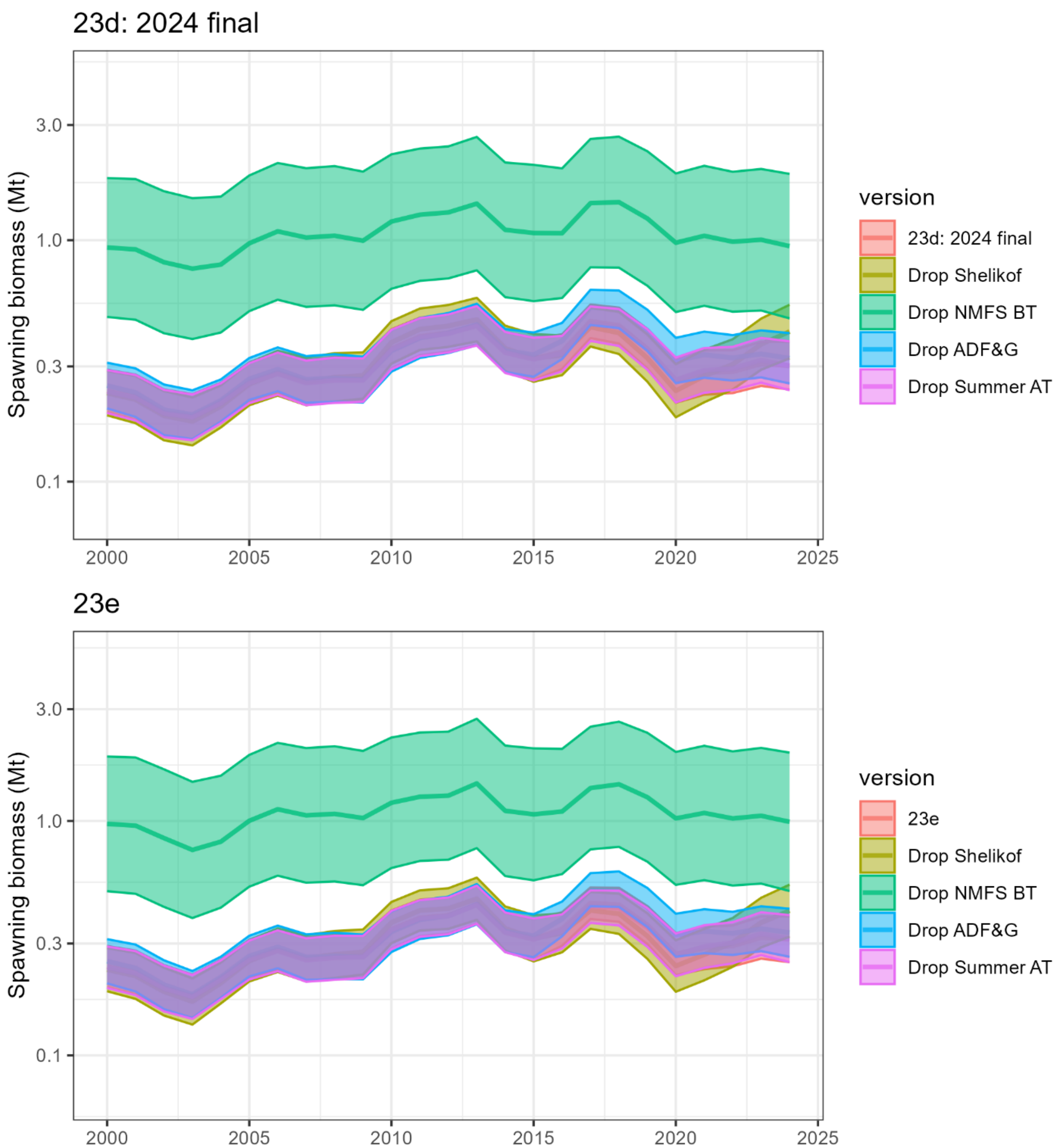


Figure 20. Results of sensitivity test of leaving each survey out (colors). Note the y-axis is in log scale to better highlight differences.

Recommendations

The proposed model 23e is very similar to the previously accepted model (23d) in structure, statistical behavior, and management outcomes. It has stable estimation and overall reasonable fits to the data. **I therefore propose model 23e for consideration in 2025 for the 2026 fishery**.

References

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